Management and Production Engineering Review
Volume 15 • Number 1 • March 2024 • pp. 35–43
DOI: 10.24425/mper.2024.149988

Fuzzy Evaluation of the Production Strategies, Policies and Methods: Evidence from a Longitudinal Case Study

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Received: 16 June 2023
Accepted: 30 November 2023

Abstract
This paper presents a model for evaluating production strategies, policies and methods based on fuzzy set theory. To illustrate the application of a model, the longitudinal case study was carried out in the sector of automotive components and parts production in Serbia. Within the automotive supplier industry, analysis is concentrated on the Cooper Standard company, one of the world's most prominent component suppliers. The study was conducted with the management team of the Cooper Standard branch in Serbia. Triangular fuzzy numbers are employed to effectively evaluate the critical areas of production management and overall competitiveness over time. The findings of the empirical survey confirmed the usability and usefulness of the proposed approach. Also, the longitudinal character of this case study provided an opportunity to follow the patterns of change over a period of 5 years (2019–2024).

Keywords
Fuzzy sets; fuzzy triangular numbers; production management; automotive suppliers.

Introduction

A trend of high production fragmentation and regionalization in the automotive industry is particularly reflected in the globalization of automotive parts and components production and the increased competition among suppliers of these inputs (Gracia & Paz, 2017; Pavlinek, 2020). A literature that focuses specifically on the automotive sector in developing countries reveals that emerging countries and the globalization encourage carmakers to assemble vehicles and to supply parts in distant countries in order to reduce costs and gain new markets (Lim et al., 2014). In Europe, it refers to the relocation of production and employment from the high-wage European countries to the Central and Eastern European, low-wage countries (Jurgens & Krzywdzinski, 2009; Krzywdzinski, 2014; Gerocs & Pinkasz, 2019; Grodzicki & Skrzypek, 2020).

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Significant and dynamic changes in the automotive components and parts production sector led to the formation of global suppliers characterized by an increasingly important role in the innovation and the allocation of investment (Sturgeon et al., 2009). Nevertheless, lead manufacturing firms in the automotive industry, through their corporate and market strength, still hold the power to determine which suppliers will be included or excluded from the value chain.

One of the possible responses of suppliers to such challenges could be to upgrade their production, in the sense of employing more efficient production strategies, engaging in the production of higher value-added products and/or increasing the skill content of organizational activities (Pavlinek & Zenka, 2011). Similarly, (Manello and Calabrese (2019) argue that beside technical skills and logistical capabilities, managerial competences should be another essential aspect for successful competing in changing environments and maintaining reliable relationship with carmakers. In that sense, evaluation of the production strategies, policies and methods must be viewed as continuing process that provides relevant information about the competitive advantage (Bourne et al., 2018).

Such evaluation is most commonly performed by management team and therefore represents self-appraisal organizational process connected to the planning, reporting and control activities. When assessing different facets of manufacturing performance, organizations usually use a form of rating scale to gather manager's subjective judgements about production processes, but the issue what is the most appropriate method for the assessment continues to present a challenge, especially under the conditions of uncertainty caused by the imprecise or incomplete data.

Since human expressions and judgments that include preferences are often vague and cannot be described precisely or estimated with exact numerical values (Wu & Chen, 2011), the fuzzy methodology could be recommended as a useful quantitative tool to grasp such uncertainty and enable a better representation of the subjective judgements. Generally, fuzzy logic has provided a wide range of tools able to deal with uncertainty in different kinds of problems in industry and decision making, including production management (Rodriguez et al., 2014; Bustince et al., 2016; Alves Ferreira et al., 2022); for example, there are many variants of interval-valued fuzzy sets, under various names, which are proposed as a natural extension of fuzzy sets (Dubois & Prade, 2005).

As Zadeh (2015) stated, fuzzy logic enables a progression from binarization to graduation, meaning that it implies the association of a class with unsharp boundaries (e.g., most words in natural language are labels of such classes) with degrees or grades of membership. That aspect of fine-grained variation through degrees of membership serves as a basis for precise measurement. Fuzzy sets are simultaneously qualitative and quantitative and may be viewed as a middle route between quantitative and qualitative measurement, transcending the limitations of both (Ragin, 2008). In essence, fuzzy set theory allows converting of verbal expressions into mathematical ones and effectively quantifies the imprecision inherent in subjective assessments (Kahraman & Yavuz, 2010).

In this paper, triangular fuzzy numbers are employed to evaluate production strategies, policies and methods in the sector of automotive suppliers. To illustrate the application of the proposed approach, evidence was provided by a longitudinal case study about the Cooper Standard branch in Serbia.

After the introductory section, the paper is organized as follows. Section 2 describes the proposed evaluation model based on fuzzy set theory. Section 3 presents a five-year longitudinal case study of the Cooper Standard branch in Serbia. Finally, some concluding remarks appear in Section 4.

Fuzzy model of evaluation

In the fuzzy evaluation model it is formulated that P_i, $i = 1, 2, \ldots, n$ represents one of n parameters for evaluation of production strategies, policies and methods. Each parameter is assessed by using linguistic variable "Competitive position" (Fig. 1) which contains five triangular numbers:

"Substantial competitive disadvantage":

$$\overline{\text{SuCD}} : [0.1] \to [0,1]; \quad \overline{\text{SuCD}}(P_i) = 1 - P_i \tag{1}$$

"Slight competitive disadvantage":

$$\overline{\text{SlCD}} : [0,2] \to [0,1]; \quad \overline{\text{SlCD}}(P_i) = \begin{cases} P_i, & 0 \le P_i \le 1 \\ 2 - P_i, & 1 \le P_i \le 2 \end{cases} \tag{2}$$

"Neither a competitive advantage nor disadvantage":

$$\overline{\text{NCAD}} : [1,3] \to [0,1]; \quad \overline{\text{NCAD}}(P_i) = \begin{cases} P_i - 1, & 1 \le P_i \le 2 \\ 3 - P_i, & 2 \le P_i \le 3 \end{cases} \tag{3}$$

"Slight competitive advantage":

$$\overline{\text{SlCA}} : [2,4] \to [0,1]; \quad \overline{\text{SlCA}}(P_i) = \begin{cases} P_i - 2, & 2 \le P_i \le 3 \\ 4 - P_i, & 3 \le P_i \le 4 \end{cases} \tag{4}$$

"Substantial competitive advantage":

$$\overline{\text{SuCA}} : [3,4] \to [0,1]; \quad \overline{\text{SuCA}}(P_i) = P_i - 3 \tag{5}$$

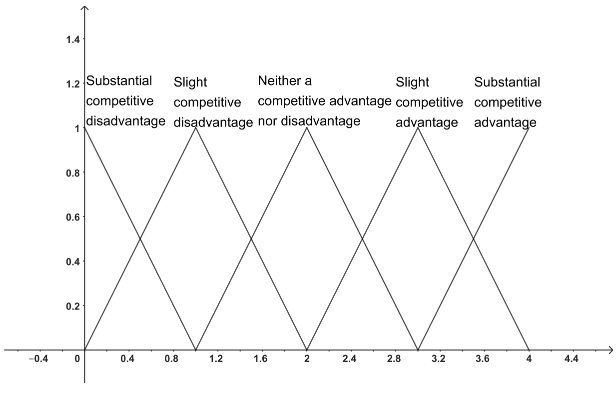

Fig. 1. Linguistic variable – competitive position

Each parameter belongs to certain fuzzy sets with a certain degree from the interval $[0, 1]$. For example, let the parameter P_i be assigned an initial value of 3.4 (the parameters are assigned values from the interval $[0, 4]$), then it belongs to the set $\overline{\text{SlCA}}$ (Slight competitive advantage) with the degree 0.6 (because $\overline{\text{SlCA}}(P_i) = 4 - P_i = 4 - 3.4 = 0.6$), and at the same time it belongs to the set $\overline{\text{SuCA}}$ (Substantial competitive advantage) with the degree 0.4 (because $\overline{\text{SuCA}}(P_i) = P_i - 3 = 3.4 - 3 = 0.4$). Next, the level of managers" assurance in estimating each parameter is also requested, thus the obtained membership degrees to fuzzy sets are also fuzzified. The level of managers" assurance is denoted by α_i, with values ranging from 0 (0%) to 1 (100%). Each number from the interval representing the membership degree of the parameter to the fuzzy set is displayed as a triangular fuzzy number $\overline{\text{SPP}_i} = (o, x_i, 1)$.

$$\overline{\text{SPP}_i}\,(x) = \begin{cases} \dfrac{x}{x_i}, & x \le x_i \\ \dfrac{x-1}{x_i-1}, & x > x_i \end{cases} \tag{6}$$

Hence, firstly, the obtained membership degrees to each fuzzy set are displayed as triangular fuzzy numbers, and then, by making α-cut, a real number representing the membership degree of the parameter to one of the fuzzy sets is displayed as a new triangular fuzzy number (x_{il}, x_i, x_{ir})

$$\begin{aligned} x_{il} &= \alpha \cdot x_i \\ x_{ir} &= \alpha \cdot (x_i - 1) + 1 \end{aligned} \tag{7}$$

In this way the confidence interval (x_{il}, x_{ir}) is obtained (Fig. 2).

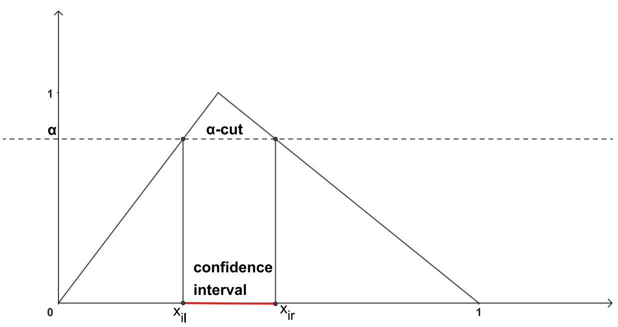

Fig. 2. Confidence interval (x_{il}, x_{ir}).

For example, for the case of a production parameter whose initial value was 3.4, and the degree of membership to sets $\overline{\text{SlCA}}$ and $\overline{\text{SuCA}}$ was 0.6 and 0.4 respectively, if the manager's confidence in the estimate was 0.8 (meaning that manager is 80% confident in the estimate), the following triangular fuzzy numbers would be obtained: (0.48, 0.6, 0.68) (Figure 3) and (0.32, 0.4, 0.52) (Figure 4), with confidence intervals (0.48, 0.68) and (0.32, 0.52).

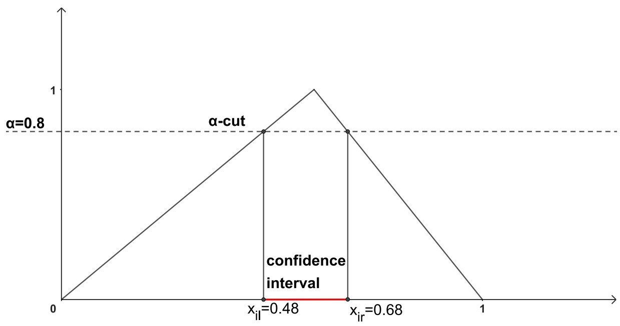

Fig. 3. Confidence interval (0.48, 0.68) of membership degree to the set $\overline{\text{SlCA}}$ obtained by 0.8-cut.

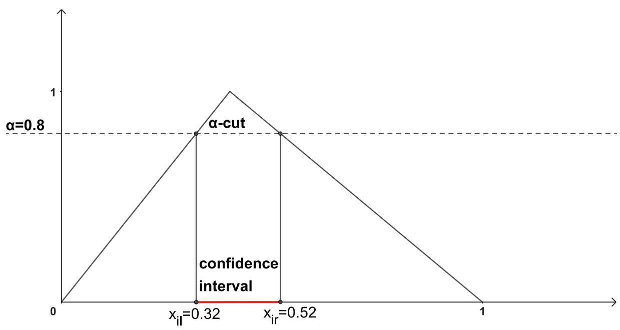

Fig. 4. Confidence interval (0.32, 0.52) of membership degree to the set $\overline{\text{SuCA}}$ obtained by 0.8-cut.

Although there are numerous methods of defuzzification (Marek-Kolodziej & Lapunka, 2020), in this paper, the ACD (alfa-cut defuzzification) method is used for defuzzification, which assigns a crisp number to a triangular fuzzy number (x_{il}, x_i, x_{ir}), according to the formula (Pourabdollah et al., 2020):

$$ACD = \frac{x_{il} + 4 \cdot x_i + x_{ir}}{6} \tag{8}$$

Finally, the fuzzy weighted average is calculated.

Case study

Data collection and sample

In order to test the proposed approach, a case study has been carried out in the automotive supplier sector in Serbia. The Serbian automotive industry has been chosen for the research primarily due to its significant economic impacts and increasing competition among automotive suppliers. Namely, this highly competitive sector supplies almost all major European car manufacturers and generally plays an important role within the whole domestic economy. It is worth noting that experience in automotive industry, availability of skilled workforce and low labor costs in Serbia attracted foreign investors from Germany, the United States, Italy, France and other countries. For the purpose of this study, Cooper Standard Automotive Inc. was singled out of the significant number of global component suppliers operating in Serbia.

The Cooper Standard company headquartered in Northville, Michigan USA has a long tradition of being a prominent automotive supplier with more than 60 years of experience. Today, this company is one of the leading global suppliers of motor vehicle parts and accessories, with locations in 21 countries. In this study, we focus on the Serbian branch of the company that employs more than 600 workers and produces sealing and fluid handling systems and components for the entire European market. Beside market competitiveness, we also considered factors such as eligibility and access to key personnel when choosing the company for the longitudinal case study.

The empirical research was conducted over five years, with data sampling taking place in January 2019, January 2021, and January 2024. With a view to select respondents who can be expected to have the best knowledge about the production strategies, policies and methods, only managers on higher managerial levels were examined. The self-administered questionnaires were hand delivered by our contact person employed at Cooper Standard. In each of the three testing, managers were instructed to complete the questionnaires in the manner requested.

Research instrument

The case study was conducted through a research instrument adopted from the validated Jenster's and Hussey's framework (Jenster & Hussey, 2001). The questionnaire comprising 25 items is divided into four following domains: production strategy; equipment and production techniques; production and quality control; purchasing and inventory management.

Specifically, in the domain of production strategy there are 3 parameters cited: (1) P_1: The level of achieving world class performance, (2) P_2: Ability to meet customer needs on the continuum from local to global production, (3) P_3: Using the concept of the focused factory. The domain of equipment and production techniques include 7 parameters: (1) P_1: Matching of production facilities with the current and future needs, (2) P_2: Capability of machinery to meet desired production output, (3) P_3: Space utilization, (4) P_4: Current state of production techniques comparing to other alternatives, (5) P_5: Handling maintenance, (6) P_6: Using prospective possibilities for outsourcing (7) P_7: The state of production equipment in comparison with the available technical possibilities. Next domain of production and quality control involve 9 parameters: (1) P_1: Calculating lead time, (2) P_2: Production scheduling, (3) P_3: Processing of rush orders, (4) P_4: Monitoring and controlling of production schedules, (5) P_5: Material flow planning, (6) P_6: Workspace tidiness and organization, (7) P_7: Using organized form of quality control, (8) P_8: Production compliance with standards, tolerances and instructions, (9) P_9: Measurement and quality control techniques. Finally, in the domain of purchasing and inventory management there are 6 parameters: (1) P_1: The utilization of vendor performance evaluation, (2) P_2: Managing the supply of materials, (3) P_3: Performing the systematic receiving control with regard to quality and quantity of purchases, (4) P_4: Procurement of production tools, (5) P_5: Inventory control procedures, (6) P_6: Evaluating purchasing and stock order sizes).

Managers assessed the value of each parameter on a scale from 0 (indicating substantial competitive disadvantage) to 4 (indicating substantial competitive advantage). The parameters were estimated by the fuzzy linguistic variable "competitive position" i.e., the degrees of membership of the parameters to fuzzy sets $\overline{\text{SuCD}}$, $\overline{\text{SlCD}}$, $\overline{\text{NCAD}}$, $\overline{\text{SlCA}}$ and $\overline{\text{SuCA}}$ were obtained. Then, by making α-cut (the manager's degree of confidence in his assessment, i.e., the degree of belief) each parameter is displayed as a new triangular fuzzy number (x_{il}, x_i, x_{ir}) and the confidence interval $(x_{il}x_{ir})$ is obtained. In order to address the issue of manager credibility in providing their assessments, the presented method introduces an $\alpha-$ parameter, allowing managers to gauge the extent of confidence in their evaluations. This way, the influence of the obtained responses is weighted in determining the final rating, thereby increasing the overall credibility of the assessment. The ACD method was used for defuzzification. The fuzzy weighted average was calculated for all four domains and the overall production management function.

In order to present the questions more clearly, the questionnaire also contained suggestions for scoring the answers derived from the good practice observed in many manufacturing organizations.

The suggestions are in the form of specific examples for the assessment in the following ranks: from 0 to 1; from 1 to 2; from 2 to 3; from 3 to 4. For example, when evaluate competitive position of parameter P_5

(Material flow planning) in the domain of production and quality control, suggestions are expressed in the following manner: 0–1 (No plan for material supply exist, so that operators procure materials placed at different places in the warehouse); 1–2 (There is sort of regulated material supply in a sense that materials are located at designated places, also there is assistance with the logistics); 2–3 (Material supply is adequately organized which means that supplement of key materials is by inventory on schedule while less important materials are supplied by the request); 3–4 (There is a strict planning form for the delivery of materials, meaning that operators always get needed materials at the workstations).

Examples serve as an aid to managers when assessing competitive positions of production management domains.

Results and discussion

The case study used a longitudinal design, involving repeated measurements of managers" attitudes at fixed intervals. The first survey was conducted in January 2019.

The grades of competitive positions for each parameter and managers" confidence in the assessment were obtain based on completed questionnaires. Then, using fuzzy evaluation model a fuzzy grade of competitive position for each parameter and a confidence interval were calculated. The results are shown in Table 1.

Table 1 demonstrates that domain of production strategy was rated significantly high whilst the three other domains were rated lower. This could be largely attributed to the fact that dedication to the world class performance in a sense of long-term strategic commitment and global thinking kept up with the changing requirements are embedded in Cooper Standard vision and mission statements. Also, factory for car sealing systems in Serbia follow the concept of focused factory.

In the remaining three domains, the parameters were evaluated relatively uniformly with the following being ranked highest: "Using organized form of quality control", "Production compliance with standards, tolerances and instructions" and "Measurement and quality control techniques".

On the other hand, two parameters were singled out with the lowest ratings. The first parameter is "Using prospective possibilities for outsourcing", and the second one is "Processing of rush orders".

The results of the second survey, held two years later in January 2021, show visible differences in the ranking of parameters (Tab. 2).

Namely, it is noticeable that parameters from all four domains were rated with somewhat lower grades compared to the previous testing.

Table 1
Evaluation of production strategies, policies and methods in January 2019

Parameter	Grade of competitive position	Confidence in the assessment	Fuzzy grade of competitive position	Confidence interval	ACD
Production strategy					
P1	3.5	0.9	$\overline{\text{SlCA}} = 0.5$ $\overline{\text{SuCA}} = 0.5$	(0.45, 0.55) (0.45, 0.55)	0.5 0.5
P2	3.5	0.8	$\overline{\text{SlCA}} = 0.5$ $\overline{\text{SuCA}} = 0.5$	(0.4, 0.6) (0.4, 0.6)	0.5 0.5
P3	4.0	1.0	$\overline{\text{SuCA}} = 1$	1	1
Fuzzy weighted average 1					3.33
Equipment and production techniques					
P1	3.0	0.8	$\overline{\text{SlCA}} = 1$	(0.8, 1)	0.97
P2	3.0	0.8	$\overline{\text{SlCA}} = 1$	(0.8, 1)	0.97
P3	2.8	0.7	$\overline{\text{NCAD}} = 0.2$ $\overline{\text{SlCA}} = 0.8$	(0.14, 0.44) (0.56, 0.86)	0.23 0.77
P4	3.0	0.5	$\overline{\text{SlCA}} = 1$	(0.5, 1)	0.92
P5	2.8	0.8	$\overline{\text{NCAD}} = 0.2$ $\overline{\text{SlCA}} = 0.8$	(0.16, 0.36) (0.64, 0.84)	0.22 0.78
P6	2.5	0.7	$\overline{\text{NCAD}} = 0.5$ $\overline{\text{SlCA}} = 0.5$	(0.35, 0.65) (0.35, 0.65	0.5 0.5
P7	3.0	0.9	$\overline{\text{SlCA}} = 1$	(0.9, 1)	0.98
Fuzzy weighted average 2					2.86
Production and quality control					
P1	3.0	0.8	$\overline{\text{SlCA}} = 1$	(0.8, 1)	0.97
P2	3.5	0.8	$\overline{\text{SlCA}} = 0.5$ $\overline{\text{SuCA}} = 0.5$	(0.4, 0.6) (0.4, 0.6)	0.5 0.5
P3	2.5	0.9	$\overline{\text{NCAD}} = 0.5$ $\overline{\text{SuCA}} = 0.5$	(0.45, 0.55) (0.45, 0.55)	0.5 0.5
P4	3.0	0.9	$\overline{\text{SlCA}} = 1$	(0.9, 1)	0.98
P5	3.0	0.9	$\overline{\text{SlCA}} = 1$	(0.9, 1)	0.98
P6	3.2	0.7	$\overline{\text{SlCA}} = 0.8$ $\overline{\text{SuCA}} = 0.2$	(0.56, 0.86) (0.14, 0.44)	0.77 0.23
P7	3.8	0.9	$\overline{\text{SuCA}} = 0.8$ $\overline{\text{SlCA}} = 0.2$	(0.72, 0.82) (0.18, 0.28)	0.79 0.21
P8	4.0	1.0	$\overline{\text{SuCA}} = 1$	1	1
P9	3.8	0.9	$\overline{\text{SuCA}} = 0.8$ $\overline{\text{SlCA}} = 0.2$	(0.72, 0.82) (0.18, 0.28)	0.79 0.21
Fuzzy weighted average 3					2.73

Table continued next page

Table 1 continued

Parameter	Grade of competitive position	Confidence in the assessment	Fuzzy grade of competitive position	Confidence interval	ACD
Purchasing and inventory management					
P1	3.0	0.8	$\overline{SICA} = 1$	(0.8, 1)	0.97
P2	2.8	0.8	$\overline{NCAD} = 0.2$ $\overline{SICA} = 0.8$	(0.16, 0.36) (0.64, 0.84)	0.22 0.78
P3	3.2	0.7	$\overline{SICA} = 0.8$ $\overline{SuCA} = 0.2$	(0.56, 0.86) (0.14, 0.44)	0.77 0.23
P4	3.0	0.5	$\overline{SICA} = 1$	(0.5, 1)	0.92
P5	2.8	0.7	$\overline{NCAD} = 0.2$ $\overline{SICA} = 0.8$	(0.14, 0.44) (0.56, 0.86)	0.23 0.77
P6	2.8	0.7	$\overline{NCAD} = 0.2$ $\overline{SICA} = 0.8$	(0.14, 0.44) (0.56, 0.86)	0.23 0.77
				Fuzzy weighted average 4	2.90
				Overall fuzzy weighted average	2.88

It is important to note that managers were less confident in their assessments during this second testing compared to the first one.

The parameters from the domain of production strategy and the domain of production and quality control received moderately high ratings, albeit the parameter "Processing of rush orders" was rated significantly lower compared to other parameters in those domains, indicating that no improvement has been achieved since 2019.

Analyzing the results in the domain of equipment and production techniques and the domain of purchasing and inventory management, it is particularly noticeable that the parameters "Space utilization" and "Handling maintenance" were substantially lower ranked than other parameters. In the first case, this may indicate that there was no entering this question into consideration or that capacity adaptation is still in progress.

A plausible explanation for the low ranking of maintenance issue could be that there was no routine maintenance regime or that repairs were done only when a decline in production quality was observed.

Although all parameters were ranked lower compared to the previous period, they still received satisfactory grades, i.e., none of the parameters were rated in the range of 0–1 (Substantial competitive disadvantage-Slight competitive disadvantage).

A third survey demonstrates some significant differences in relation to the second survey. These are presented in Table 3.

Table 2
Evaluation of production strategies, policies and methods in January 2021

Parameter	Grade of competitive position	Confidence in the assessment	Fuzzy grade of competitive position	Confidence interval	ACD
Production strategy					
P1	3.2	0.8	$\overline{SICA} = 0.8$ $\overline{SuCA} = 0.2$	(0.64, 0.84) (0.16, 0.36)	0.78 0.22
P2	3.0	0.7	$\overline{SICA} = 1$	(0.7, 1)	0.95
P3	3.2	0.8	$\overline{SICA} = 0.8$ $\overline{SuCA} = 0.2$	(0.64, 0.84) (0.16, 0.36)	0.78 0.22
				Fuzzy weighted average 1	3.07
Equipment and production techniques					
P1	2.9	0.6	$\overline{SICA} = 0.9$ $\overline{NCAD} = 0.1$	(0.54, 0.94) (0.06, 0.46)	0.85 0.15
P2	2.8	0.7	$\overline{NCAD} = 0.2$ $\overline{SICA} = 0.8$	(0.14, 0.44) (0.56, 0.86)	0.23 0.77
P3	2.0	0.5	$\overline{NCAD} = 1$	(0.5, 1)	0.92
P4	2.8	0.7	$\overline{NCAD} = 0.2$ $\overline{SICA} = 0.8$	(0.14, 0.44) (0.56, 0.86)	0.23 0.77
P5	2.0	0.7	$\overline{NCAD} = 1$	(0.7, 1)	0.95
P6	2.8	0.7	$\overline{NCAD} = 0.2$ $\overline{SICA} = 0.8$	(0.14, 0.44) (0.56, 0.86)	0.23 0.77
P7	2.8	0.8	$\overline{NCAD} = 0.2$ $\overline{SICA} = 0.8$	(0.16, 0.36) (0.64, 0.84)	0.22 0.78
				Fuzzy weighted average 2	2.57
Production and quality control					
P1	3.2	0.8	$\overline{SICA} = 0.8$ $\overline{SuCA} = 0.2$	(0.64, 0.84) (0.16, 0.36)	0.78 0.22
P2	3.0	0.7	$\overline{SICA} = 1$	(0.7 ,1)	0.95
P3	2.5	0.7	$\overline{NCAD} = 0.5$ $\overline{SICA} = 0.5$	(0.35, 0.65) (0.35, 0.65)	0.50 0.50
P4	3.5	0.8	$\overline{SICA} = 0.5$ $\overline{SuCA} = 0.5$	(0.4, 0.6) (0.4, 0.6)	0.50 0.50
P5	3.0	0.8	$\overline{SICA} = 1$	(0.8, 1)	0.97
P6	3.0	0.7	$\overline{SICA} = 1$	(0.7, 1)	0.95
P7	3.7	0.9	$\overline{SuCA} = 0.7$ $\overline{SICA} = 0.3$	(0.63, 0.73) (0.27, 0.37)	0.69 0.31
P8	3.7	0.9	$\overline{SuCA} = 0.7$ $\overline{SICA} = 0.3$	(0.63, 0.73) (0.27, 0.37)	0.69 0.31
P9	3.5	0.9	$\overline{SICA} = 0.5$ $\overline{NCAD} = 0.5$	(0.45, 0.55) (0.45, 0.55)	0.50 0.50
				Fuzzy weighted average 2	3.01

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Table 2 continued

Parameter	Grade of competitive position	Confidence in the assessment	Fuzzy grade of competitive position	Confidence interval	ACD
Purchasing and inventory management					
P1	2.5	0.7	$\overline{\text{NCAD}}=0.5$ $\overline{\text{SlCA}}=0.5$	(0.35, 0.65) (0.35, 0.65)	0.50 0.50
P2	2.5	0.7	$\overline{\text{NCAD}}=0.5$ $\overline{\text{SlCA}}=0.5$	(0.35, 0.65) (0.35, 0.65)	0.50 0.50
P3	3.0	0.7	$\overline{\text{SlCA}}=1$	(0.7, 1)	0.95
P4	2.8	0.6	$\overline{\text{NCAD}}=0.2$ $\overline{\text{SlCA}}=0.8$	(0.12, 0.52) (0.48, 0.88)	0.24 0.76
P5	2.9	0.6	$\overline{\text{SlCA}}=0.9$ $\overline{\text{NCAD}}=0.1$	(0.54, 0.94) (0.06, 0.46)	0.85 0.15
P6	2.5	0.6	$\overline{\text{NCAD}}=0.5$ $\overline{\text{SlCA}}=0.5$	(0.3, 0.7) (0.3, 0.7)	0.50 0.50
				Fuzzy weighted average 4	2.68
				Overall fuzzy weighted average	2.81

Firstly, managers were much more confident in their assessments than they did under the previous testing, and secondly, they gave higher ratings to almost all parameters.

Using the responses of all three testing periods, the results indicate that the parameters pertaining to production space and maintenance varied considerably along a continuum from "Neither a competitive advantage nor disadvantage" to "Slight competitive advantage" and "Substantial competitive advantage".

The 2024 survey results shows that managers seemed confident that capacity problems are limited with the tendency to be completely resolved, for example, using periodic capacity utilization and workflow studies that may result in rearrangement of machinery. Also, they expressed higher levels of confidence in the assessment that maintenance is significantly improved which may indicate that machines were maintained according to a regular schedule and that repairs were done at the end of each production shift.

This strongly suggest that the interventions after the second survey positively affected performance.

Potential technological advancements that could enhance our model include: incorporating state-of-the-art machine learning algorithms to refine the accuracy and predictive capabilities of the model., leveraging big data analytics to handle larger datasets, extracting more meaningful insights, and improving the model's robustness, implementing real-time data processing capabilities to enable the model to adapt and respond

Table 3
Evaluation of production strategies, policies and methods in January 2024

Parameter	Grade of competitive position	Confidence in the assessment	Fuzzy grade of competitive position	Confidence interval	ACD
Production strategy					
P1	3.5	0.9	$\overline{\text{SlCA}}=0.5$ $\overline{\text{SuCA}}=0.5$	(0.45, 0.55) (0.45, 0.55)	0.5 0.5
P2	3.5	0.8	$\overline{\text{SlCA}}=0.5$ $\overline{\text{SuCA}}=0.5$	(0.4, 0.6) (0.4, 0.6)	0.5 0.5
P3	4.0	1.0	$\overline{\text{SuCA}}=1$	1	1
				Fuzzy weighted average 1	3.33
Equipment and production techniques					
P1	3.0	0.8	$\overline{\text{SlCA}}=1$	(0.8, 1)	0.97
P2	3.5	0.9	$\overline{\text{SlCA}}=0.5$ $\overline{\text{SuCA}}=0.5$	(0.45, 0.55) (0.45, 0.55)	0.5 0.5
P3	3.2	0.8	$\overline{\text{SlCA}}=0.8$ $\overline{\text{SuCA}}=0.2$	(0.64, 0.84) (0.16, 0.36)	0.78 0.22
P4	3.5	0.9	$\overline{\text{SlCA}}=0.5$ $\overline{\text{SuCA}}=0.5$	(0.45, 0.55) (0.45, 0.55)	0.5 0.5
P5	3.5	0.8	$\overline{\text{SlCA}}=0.5$ $\overline{\text{SuCA}}=0.5$	(0.4, 0.6) (0.4, 0.6)	0.5 0.5
P6	3.0	0.8	$\overline{\text{SlCA}}=1$	(0.8, 1)	0.97
P7	3.2	0.8	$\overline{\text{SlCA}}=0.8$ $\overline{\text{SuCA}}=0.2$	(0.64, 0.84) (0.16, 0.36)	0.78 0.22
				Fuzzy weighted average 2	3.14
Production and quality control					
P1	3.2	0.9	$\overline{\text{SlCA}}=0.8$ $\overline{\text{SuCA}}=0.2$	(0.72, 0.82) (0.18, 0.28)	0.79 0.21
P2	3.5	0.8	$\overline{\text{SlCA}}=0.5$ $\overline{\text{SuCA}}=0.5$	(0.4, 0.6) (0.4, 0.6)	0.5 0.5
P3	3.0	0.8	$\overline{\text{SlCA}}=1$	(0.8, 1)	0.97
P4	3.8	0.9	$\overline{\text{SuCA}}=0.8$ $\overline{\text{SlCA}}=0.2$	(0.72, 0.82) (0.18, 0.28)	0.79 0.21
P5	3.2	0.8	$\overline{\text{SlCA}}=0.8$ $\overline{\text{SuCA}}=0.2$	(0.64, 0.84) (0.16, 0.36)	0.78 0.22
P6	3.2	0.8	$=0.8$ $=0.2$	(0.64, 0.84) (0.16, 0.36)	0.78 0.22
P7	4.0	1.0	$\overline{\text{SuCA}}=1$	1	1
P8	4.0	1.0	$\overline{\text{SuCA}}=1$	1	1
P9	3.8	0.9	$\overline{\text{SuCA}}=0.8$ $\overline{\text{SlCA}}=0.2$	(0.72, 0.82) (0.18, 0.28)	0.79 0.21
				Fuzzy weighted average 3	3.26

Table continued next page

Table 3 continued

Parameter	Grade of competitive position	Confidence in the assessment	Fuzzy grade of competitive position	Confidence interval	ACD
Purchasing and inventory management					
P1	3.0	0.7	$\overline{\text{SlCA}} = 1$	(0.7, 1)	0.95
P2	3.5	0.8	$\overline{\text{SlCA}} = 0.5$ $\overline{\text{SuCA}} = 0.5$	(0.4, 0.6) (0.4, 0.6)	0.5 0.5
P3	3.2	0.8	$\overline{\text{SlCA}} = 0.8$ $\overline{\text{SuCA}} = 0.2$	(0.64, 0.84) (0.16, 0.36)	0.78 0.22
P4	3.0	0.8	$\overline{\text{SlCA}} = 1$	(0.8, 1)	0.97
P5	3.2	0.8	$\overline{\text{SlCA}} = 0.8$ $\overline{\text{SuCA}} = 0.2$	(0.64, 0.84) (0.16, 0.36)	0.78 0.22
P6	3.0	0.8	$\overline{\text{SlCA}} = 1$	(0.8, 1)	0.97
Fuzzy weighted average 4					3.08
Overall fuzzy weighted average					3.19

quickly to dynamic changes in the input data, exploring the integration of blockchain for enhanced security, transparency, and traceability in the handling of data and model outputs and utilizing IoT devices to collect real-time data and feed it into the model, allowing for more dynamic and responsive decision-making.

Conclusions

This paper advocates using of fuzzy set theory in subjective evaluations of the production strategies, policies and methods employed in the automotive supplier sector. In that sense, a specific method built on triangular fuzzy numbers utilization is used in order to deal with imprecision and vagueness of manager-originated assessments.

The fuzzy method of evaluation was tested in a longitudinal case study of The Cooper Standard branch in Serbia with a view to comprehend production management competitiveness of this prominent automotive supplier over a 5-year period. It is worth noting that managers examined in the research jointly expressed only positive impressions and confirmed that research instrument used to collect primary data was clear and practical. Moreover, they agreed that evaluation based on fuzzy logic enables reducing subjectivity and uncertainty and achieving more fine-grained and realistic results.

The longitudinal character of this case study allowed generating in-depth insight pertaining to competitive strength of particular production management aspects and overall competitiveness over time. The main limitation of the study refers to the fact that results come out from such single longitudinal case study methodology cannot be generalized. It is important to clarify that this does not imply limitations of the applied method but rather underscores the necessity for future similar research in the context to draw broader conclusions that extend beyond a single company. Additionally, considering that all data was obtained through the described method and presented on the same scale, comparisons are facilitated, simplifying the analysis. Thus, further investigations should consider broadening the empirical scope of analysis and involving most or all of automotive suppliers operating in Serbia Also, it would be interesting to analyze the competitive advantage or disadvantage in production management of automotive suppliers located in Serbia with respect to the ones based in neighboring countries or other Central and Eastern European countries that experienced the similar transition and growth of the automotive supplier industry.

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